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Evolutionary Game Between Local Government and Agritourism Companies in the Context of Environmental Protection

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This study selects local government and agritourism companies to study the evolutionary game of both sides in the decision-making toward environmental protection. Based on the relevant literatures and the theory of evolutionary game, it try to establish a comparatively accurate mathematical model to verify the effectiveness of the penalty policy of the damage to the environment, then, this study explores the evolutionarily stable strategy of these two parties from the dynamic way. Research results show that, (1) When the fine of the environmental damage is bigger than the cost of the government's supervision, the agritourism companies would choose to protect the environment if the government select the strategy of supervision. (2) When the fine of the environmental damage is fewer than the cost of the government's supervision, the agritourism companies would not choose to protect the environment whatever the government select the strategy of supervision or non-supervision. (3) When the fine of the environmental damage is bigger than the sum of the administrative costs and bonuses, the agritourism enterprises would choose the strategy of protecting the environment even the government select the strategy of non-supervision.

1. Introduction

Nowadays, agritourism is famous for its contribution to the development of rural economics and the function of environmental protection. However, making these companies to achieve the function of environmental protection also needs external supervision. Actually, during the development of agritourism, due to the absence of environmental responsibility, a great amount of forests are ruthlessly cut down, the vegetation is severely damaged, the water is highly contaminated, and the wanton waste is discharged unprocessed by the agritourism companies, furthermore, some consumers that are lack of environmental conscious randomly thrown away garbage, which have produced great damage to the local ecosystem. These problems gradually attracted the attention of local government. In order to make the agritourism development in a way of low-carbon and environmental protection, they are trying to establish reasonable strategies which are in accorded with the characteristics of local ecological environment, and make sure that agritourism project are development under the premise of protecting local natural resources. Moreover, some specifications have aready been issued by the government to review the qualification of agritourism enterprises.
Nevertheless, some policies are difficult to implement due to the high costs of management and the difficulty of supervision. Thus, this study applies the evolutionary game theory to analyze the game problem between the local government and agritourism companies in the context of environmental protection with the purpose of exploring effective ways to solve the problem.

2. Literature review

This study will mainly reviews those literatures that are focus on the applications of evolutionary game theory in various conflicts issues of environmental pollution, moreover, the studies on the supervision and punishment mechanism between the local government and agritourism enterprises would be introduced as well.

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The Rational Theory of Crime raised by Becker in 1968 had caused significant repercussions, 18 years later, the study of Russell et al. (1986) on the implementation of the supervision and the enforcement of various environmental regulations had produced a significant influence on the research regarding effectiveness of environmental law. However, Harrington (1988) questioned the above research, he thought that limiting the amount of punishment can improve the efficiency of law enforcement agencies, this is the famous 'Harrington Paradox'. Later, White (1996) and other scholars further studied or explained the paradox. After the deep analysis of related data of the environmental regulations in Norwegian, Karine (2006) indicated that 'Harrington paradox' can only be a hypothesis but not a fact. From later 20th century, with the increasing awareness of environmental protection, many enterprises gradually reduced their negative impact on the environment during the production. Some scholars believed that the above behavior of these enterprises was voluntary, in response to this view, Antweiler (2000) used the recorded Canada's national emissions data to investigated the motivation of companies to reduce emissions, result showed that companies reduce emissions was not a voluntary act, but the impact results by various government regulation and public pressure. With further research, new ideas constantly being proposed, Akihiko (2009) pointed out that individual behavior in human society is not only affected by economic factors, but also influenced by other psychological factors. This view was supported by Yukari (2009), he treat various psychological factors as a social pressure, and carried out his study on the equilibrium of co-evolution trend between economic costs and social pressures. It can be found from the above research that there often exist a big difference between the reality and the results obtained when applying the complete rationality of traditional economics to analyze the environmental pollution problems in corporate behavior.

With the deep study and the development of game theory, its assumptions about the players' completely rational was considered too strict and was questioned, meanwhile, a new theory called evolutionary game is forwarded and gradually accepted by scholars. Evolutionary game theory provides people with a new way of thinking to analyze a variety of complex dynamic and long-term conflict relationship in social and economic fields. The study of Shinsuke (2008) has made outstanding contribution to the promotion of the research in this field, and the above scholars focused most of their researches on the analysis of evolutionary stable strategy (ESS). Moreover, some new ideas are brought about consequently in this field, such as individual adaptive learning mechanism in evolutionary game (Jens, 2008). These literatures had all made their further research for evolutionary game theory, they made contributions to promote evolutionary game theory system to be more abundant and maturing. Till now, there are few applications of evolutionary game in the analysis of environmental pollution problem. Yukari et al. (2009) believed that individuals in the group not only select the policy from the perspective of profit maximization, their selections are simultaneously affected by pressure from various social and psychological factors. Yukari quantified the public social pressure as an influencing factor of dynamic selection mechanism, then, he used evolutionary game to analysis the lake pollution problem, and discussed the affection of various influences such as social factors on the evolution of cooperation of different interest groups under the symmetric and asymmetric conditions.

Currently, the analysis of evolutionary game toward environmental pollution are mainly focus on the two groups, including symmetrical game between enterprises, and asymmetrical game between companies and government, but due to the limitations of mathematical analysis tools, most of the research are not related to the internal competition mechanism. Furthermore, it can be found that vast majority of the study mainly discussed the existence of the evolutionary stable strategy of the game model in the general conditions of the payoff matrix, but not consider and analyze the influence of the various environmental policies and strategies on the ESS, neither the existence of complex dynamical behavior in the game. Although countries had made many kinds of policies for the management of environmental resources, and the regulatory mechanism is the key to ensure the implementation of the laws and regulations, without a sound and effective regulatory regime, it is difficult to achieve the expected results of the implementation (Wang, 2011). In order to control the impact of the production of sewage on the environment, it is not only necessary to collect tax from the companies before pollution, but also necessary to punish them if they discharge excessive sewage (Yeung, 2008).

3. Theoretical basis

As stated above, the traditional game made a hypothesis that the parties are perfectly rational, however, this assumption is difficulty to get support in reality. Evolutionary game theory holds a more practical view that individuals are limited rationality, the individuals did not have the most favourable strategy when they participated in the game, but they would learn during the game, so the game is regarded as a process of evolution. Although there are significant differences about the assumptions, but the evolutionary game is put forward on the basis of classic game theory and the theory of evolutionary biology. Replicator dynamics and evolutionary stable strategy are two important concept of evolutionary game theory which are introduced from the theory of biological evolution. Replicator dynamics model is used to simulate the process of change of the

type of comparison groups. Replicator dynamics proved that when the fitness or payment (Pay off) of a new emergence strategy is higher than the population's average fitness, this strategy would be used by more and more participants in the population over the time. In the contrary, the underperforming policies would gradually be abandoned by race participants (Friedman，1991). In the replicator dynamics, when applying a strategy, the growth of the individual units is proportional to the difference of these individuals' fitness and the population's average fitness, it could be represented by the dynamic differential equations of (1):

$$\frac{dp}{dt} = p\left(u_k - \bar{u}\right) \tag{1}$$

In formula (1), p represents the proportion of the population that using the specific strategy k, u_k is the pay can get when using the specific strategy k, $\bar{u}$ is an average paying that population got.

In evolutionary biology, the concept of evolutionary stable strategy defines the necessary conditions for population to maintain a stable in evolution.

Evolutionary stable strategy in evolutionary game refers to the process that, in order to improve the income, the bounded rationality of individuals continue to make the appropriate adjustments to its strategy on the margin and continued to achieve the target of 'relatively satisfied situation' replacing 'relatively more satisfied situation', finally, achieving a state of dynamic equilibrium. (Hodgson, 1997).

In the analysis framework of evolutionary game theory, behavior and fitness of individual can be described by strategies and turnover, the replacement of the strategies reflects the preferred choice of law when the individual makes the selection, wherein the updating rule of strategies is determined by the process of evolutionary dynamics. Classic game theory held the view that the starting point of rational individual's behavior is to maximize their own income, but the overall benefits of the system decreased when all the individual decisions are to maximize their own interests, this is called 'social dilemma' (Chen，2012)。The reason for the appearance of 'social dilemma' is the contradiction that individuals and the group both pursue to reach the maximize income, in this ambivalence, exploring the dynamic phenomena in the process of cooperation evolution as well as better ways to promote cooperation are the main purposes to study the evolutionary game.

During the evolutionary game between local government and agritourism companies in the context of environmental protection, as the involved parties, local government and agritourism enterprises would constantly adjusted their strategies with the purpose of pursuing the max income under the premise of bounded rationality. The balance that evolutionary game emphasizes is the improved result of the model rather than choice, which is consistent with the game mechanism of local government and agritourism enterprises. Therefore, this study firstly attempt to establish an evolutionary game model to reflect the spontaneous evolution between local government and agritourism enterprises in the context of environmental protection, then, it further analyze the process of dynamic evolution, with the hope of revealing nonlinear characteristics and the evolution path of the game between the local government and agritourism enterprises.

4. Model hypothesis and model construction

4.1 Model hypothesis

In order to facilitate the analysis, this study regards the local government and agritourism companies as two parties, and assumed both parties have limited rationality and the information is incomplete.

As a regional representative of the public interest, local government carry out its mission of public governance and resource allocation by the enforcement of the right of administrative jurisdiction. In consideration of the requirements for financial support, personnel and equipment and other resources of knowledge and technology when putting the supervision into effect, and due to the high cost of the supervision, not all administrations choose the strategy of the supervising the environmental protection.

Agritourism enterprises have economic characteristics and their running goals are to maximize profits, therefore, they would comprehensively measure the relationship between the costs and performance when considering the business strategy. If the enterprises' protection measures of service delivery and production process meet government's requirements, it is considered as the enterprise that deciding to protect the environment during the development. In the contrary, traditional development is chosen. On the one hand, the strategies that agritourism companies applied are mainly based on their business performance, thus, when these organizations choosing the strategies, they would firstly take their own business objectives and marketing plan, production costs and sales revenue as well as product awareness of target tourists and demand trends of consumer into consideration. On the other hand, agritourism companies are sensitive to government's incentives, the punishment system for the damage to the environment can be the effective catalyst for these enterprises to protect the environment.

4.2 Model construction

The costs and income of the local government depend on the strategy it choose, if the government choose the strategy to encourage agritourism companies to protection environment, the government need to pay a certain amount of monitoring costs in this situation. In order to simplify the model, it is regarded as a fixed costs, meaning that the costs that government have to pay for the monitoring under a certain level of supervision, when paying this costs, the environment being exploited by the agritourism companies meet the requirements, therefore, the costs are relatively fixed. Furthermore, while the government exercising the supervision, the percentage of agritourism companies that selecting to protect the environment is enlarged, the environment getting better protection, and the government incentives for such enterprises, accordingly, the compensation expense is another supervision cost of the government. As the managers of urban public resource and the providers of public goods, its primary task is to governance the urban environment, consequently, supervision helps government to save the costs that need for the environmental governance, the costs is regarded as the income of the government when it choose the strategy of supervision. In the contrary, the governance costs consist of the expenditure when government gives up the supervision.

The costs and income of the agritourism companies depend on the strategy it choose as well, if the agritourism companies choose the strategy of protecting the environment, they have to invest a certain amount of money, this is part of their costs, but they can get some reward from the government. When the companies select the way of traditional development, it means that the companies do not invest money to protect the environment, in this situation, most of them would damage the environment, and the government would punish them by the mean of fining them money, and the money that companies have to pay for the damage of environment is their cost when they choose the strategy of traditional development.

Based on the above analysis, a pay off matrix of evolutionary game model is established in table 1.

Table 1: Pay off matrix of evolutionary game model

Game-agents and their strategies		Creative agribusinesses	
		Protect the environment	Traditional development
Local government	Supervision	$-S-R$， $R+P-I$	$F-S-T$， $P-F$
	Non-supervision	0， $P-I$	$-T$， P

In the table 1, *S* is short for supervision cost, *R* is short for the reward from the government, *F* is short for Fine, *T* is short for the environment pollution treatment that pay by the government, *P* is short for the profit that agritourism companies make when they choose the way of traditional development, *I* is short for investment that agritourism companies make to protect the environment.

Then this study assuming that the proportion of the local government select the strategy of supervision is x, and the proportion of the non supervision is 1-x, and the proportion of the agritourism companies decide to protect environment is *y*, while the proportion that choose the strategy of traditional development is 1-y. (x,y) represents the evolution dynamic of the parties in the game between local government and agritourism companies, the purpose of this study is to analyze the equilibrium state of the evolution. In the evolutionary game between local government and agritourism companies, the participants select and adjust strategies on the basis of their relative suitability. Assuming the growth rate of one strategy is equivalent to their relative flexibility, so that the strategy will be developed when it is higher than the average adaptability of the population(Friedman, 1991). It can be represented by a set of differential equations.

The expected return that local governments take supervision strategy can be represented by equation (2).

$$f_1^1 = y(-S-R)+(1-y)(F-S-T) = yT-yF-yR+F-S-T \tag{2}$$

The expected return that local governments take non-supervision strategy can be represented by equation (3).

$$f_1^2 = (y-1)T \tag{3}$$

The average expected return of the local governments can be represented by equation (4).

$$\bar{f}_1 = xf_1^1+(1-x)f_1^2 = x(yT-yF-yR+F-S-T)+(1-x)(y-1)T \tag{4}$$

Therefore, the replication dynamic equation of the local government when it chooses the strategy of supervision can be represented by equation (5).

$$f_1(x) = \frac{dx}{dt} = x(f_1^1 - \bar{f}_1) = x(1-x)(F - S - yF - yR)$$

(5)

In the same way, we can get the replication dynamic equation (6) of the agritourism companies when it choose the strategy of protecting the environment.

$$f_2(y) = \frac{dy}{dt} = y(f_2^2 - \bar{f}_2) = y(1-y)(xR + xF - F) \tag{6}$$

The replication dynamic equation reflects the learning speed and direction of the participation, and only when the replication dynamic equation is 0 which means the learning rate is 0, the game reaches a relatively stable equilibrium. Therefore, when the formula (5) and (6) are both 0, the game achieves the evolutionary equilibrium state, five balanced nodes can be obtained, there are $E_1(0,0)$, $E_2(1,0)$, $E_3(0,1)$, $E_4(1,1)$ and $E_5(x_5=F/(F+R), y_5=(F-S)/(F+R))$ respectively.

The evolution system that consists of two calculus equations of (5) and (6) describes the dynamic of the evolution game between local government and agritourism companies, and the stability of the evolutionary point of (x, y) can be calculated from the analysis of the local stability of the Jacobi (Jacbian) matrix that derived from the two differential equations. The Jacobi (Jacbian) matrix of the evolution system that consists of Formula (5) and (6) can be represented by equation (7).

$$J = \begin{bmatrix} (1-2x)(F - S - yF - yR) & x(1-x)(-F-R) \\ y(1-y)(F+R) & (1-2y)(xR + xF - F) \end{bmatrix} \tag{7}$$

5. Game result analysis

Then, this study applies the method of local stability analysis of Jacobi matrix to analyze the stability of the above equilibrium points, results are shown in the table 2.

Table 1: Pay off matrix of evolutionary game model

Equilibriums	det$J$	tr$J$	Results	Conditions
$E_1(0,0)$	+	–	ESS	$F < S$
$E_2(1,0)$	+	+	ESS	$F < S$
$E_3(0,1)$	–	Uncertain	Saddle Point	$F > S + R$
$E_4(1,1)$	–	+	ESS	$F > S$
$E_5(x_5, y_5)$	+	0	Saddle Point	Any conditions

In table 2, it can be known that $E_1(0,0)$, $E_2(1,0)$, $E_3(0,1)$, $E_4(1,1)$ are the evolutionary stable strategies of the game system, it means that the system is in steady state temporarily, but it would deviate from this state if disturbance appear. $E_4(1,1)$ shows the strategy of (supervision, protect the environment), but the premise to achieve this balance if the fine is bigger than the supervision cost. $E_1(0,0)$, $E_2(1,0)$ shows that when administrative costs is larger than the government revenues from punishment of the environmental damage, whether local governments choose supervision or non-supervision, the agritourism companies would choose the strategy of traditional development. This study has made the hypothesis that the government's supervision costs are fixed, so the cost of damage to the environment is an important driving factor in the promotion of agritourism companies to choose environmentally friendly development path, so the government should rethink the punishment intensity of the damage to the environment. $E_3(0,1)$ shows that when the fine of the environmental damage is bigger than the sum of the administrative costs and bonuses. The agritourism enterprises would choose the strategy of protecting the environment even the government select the strategy of non-supervision. In summary, in the evolutionary game between local government and agritourism companies in the context of environmental protection, The punishment of the damage to the environment is the most important factor that influencing the choices of the agritourism companies, the greater the punishment, the more companies will protect the environment, therefore, the government should base on its demands of environmental protection, and establish a reasonable punitive measures to urge the enterprises to consciously choose green development, thus promoting the sustainable development of leisure agriculture.

6. Conclusion

In order to explore the evolution mechanism of the game between the local government and the agritourism companies in context of environmental protection, this study applies evolution game theory to analyze the reasons of strategy chosen of the parties involving in the game. After the analysis of the parties benefits and the setting of the assumptions, it establishes a game model and analyze the game result, this study concludes as follow, (1) when the fine of the environmental damage is bigger than the cost of the government's supervision, the agritourism companies would choose to protect the environment if the government select the strategy of supervision, (2) when the fine of the environmental damage is smaller than the cost of the government's supervision, the agritourism companies would not choose to protect the environment whether the government select the strategy of supervision or non-supervision, (3) when the fine of the environmental damage is bigger than the sum of the administrative costs and bonuses. The agritourism enterprises would choose the strategy of protecting the environment even the government select the strategy of non-supervision. Results also reveals that the amount of the fine is the most important factor that affecting the strategy selection of the agritourism companies which is consistent with the status in China, therefore, in order to promote the agritourism companies better protect the environment, local government should thoroughly analyze the existing penalty system, and continuously increase the costs of the damage to the environment of agritourism enterprises so that these enterprises can be more consciously to protect the environment, furthermore, these measures can also promote the leisure agriculture to be development in a sustainable way, thus promoting the continuous development of the local economy.

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